

Title: Hold That Note**Brief Overview:**

A vibrating tuning fork disturbs air molecules and creates compressions (regions of higher than normal pressure) and rarefactions (regions of lower than normal pressure). These pressure variations can be digitized with a microphone, transferred to a calculator, and displayed on its screen as a sinusoidal curve. The addition of two or more of these sinusoidal curves is referred to as superposition. The concept of superposition is tied to the amplification of sound. This activity is designed to study the properties of a sinusoidal curve created by superposition.

Links to Standards:

- **Mathematics as Problem Solving**
Students will investigate the concept of superposition through experimentation with sound waves.
- **Mathematics as Communication**
Students will express mathematical concepts both orally and in writing.
- **Mathematics as Reasoning**
Students will be asked to predict a solution to a problem and then test its validity.
- **Mathematical Connections**
Students will investigate connections between mathematics, sound, and music.
- **Algebra**
Students will apply knowledge of tables, graphs, equations, mathematical operations, and estimation.
- **Trigonometry**
Students will apply knowledge of period, amplitude, and frequency of a sinusoidal curve.

Grade/Level:

Grades 9-12, Algebra 1, Algebra 2, Trigonometry, Physical Science, Physics

Duration/Length:

This activity is designed for two days, one day for the introductory lesson and one day for the student sound lesson. A third day may be necessary for discussion and wrap up.

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- □ Reading and interpreting tables
- □ Using the CBL and the TI-82 to collect data
- □ Working with shifting of and math operations on the tables of the TI-82
- □ Graphing on the TI-82 (including graphing multiple Stat-Plots)

Objectives:

Students will:

- □ collect and organize data.
- □ work individually and in groups.
- □ use the CBL and the TI-82 to collect data.
- □ shift and add lists on the TI-82.
- □ predict results based on given data.
- □ compare predicted outcomes to actual outcomes.
- □ create frequency graphs.
- □ draw conclusions related to music.
- □ use written and oral communication effectively.

Materials/Resources/Printed Materials:

- □ 1 CBL for each group
- □ 2 TI-82 calculators for each group
- □ 1 Vernier microphone and DIN adapter for each group
- □ 2 tuning forks of the same frequency for each group
- □ 1 copy of program MIC on each TI-82 (copy included)

Development/Procedures:

- The teacher should use the Prerequisite Help List that is included at the end of this unit or an alternate procedure they develop to collect data and enter it into lists. Follow the step-by-step procedure with the students as detailed on the Prerequisite Help List.
- With another set of data, demonstrate the steps of the procedure for transferring data from list to list as outlined in the teacher notes.
- The teacher should demonstrate to the students how to connect the CBL to the TI-82, and the CBL to the Vernier microphone. The teacher should next demonstrate how to start the MIC program, strike the tuning fork and place the tuning fork over the microphone to collect the data. Next the teacher should connect a different TI-82 to the CBL and do the demonstration again to collect a second set of data.

- Students should collect data for each part of the experiment and follow the directions on the worksheets to complete the data gathering and transferring of data to different lists on one calculator.
- Students should graph each of the different results using the STAT-PLOT. The students should graph the sinusoidal curve representing the sum of the two individual tuning forks, and the sinusoidal curve of the two tuning forks together on the same graph using STAT-PLOT.
- The results of the experiment should be discussed, including why their results may not have been as accurate as expected.
- The teacher should give a brief overview of the follow-up activity involving the same experiment with students voices rather than tuning forks.

Performance Assessment:

- The teacher will circulate in the classroom and offer assistance to the students. Students will be evaluated in the areas of participation, accuracy of calculations, completion of assignments (worksheets, tables, graphs), and proficiency with the TI-82 and the CBL. The students should not be greatly penalized if the predicted combination curve does not accurately match the curve created by the two tuning forks at once.

Extension/Follow Up:

- □ Same experiment using student voices instead of tuning forks
- Study of sinusoidal curves including amplitude, period, and phase shift
- Projects on the relationship between frequencies and music
 - Study of resonance, harmony, discordance, and beat
 - Study of chords on musical instruments

Authors:

Fran Imbrescia
Washington-Lee High School
Arlington, Virginia

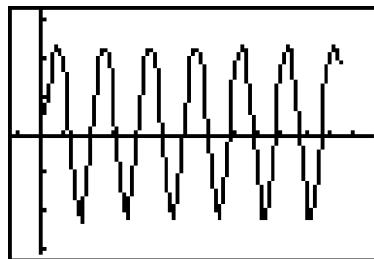
Name: Helen Snyder
School: Lake Braddock High School
Fairfax, Virginia

James Hale
Graham High School
Tazewell County, Virginia

TEACHER NOTES
OUTLINE OF A SAMPLE EXPERIMENT

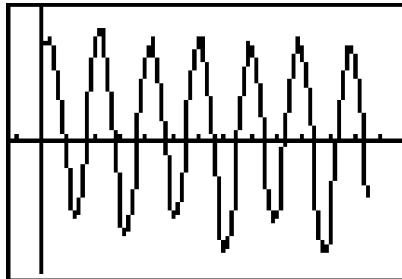
1. Using CBL, TI-82(1) and Tuning Fork(1) run the program MIC and collect the data.
 - A. Raw data is entered in L₅ and L₆
 - B. Adjusted data is entered in L₁ and L₂
 - C. Then plot the information using STAT PLOT

L1	L2	L3
RAW DATA	.28995	-----
5.7E-4	.54837	
8.3E-4	.78309	
.00108	1.0081	
.00133	1.1189	
.00158	1.0932	
.00183	.93981	
L1(1)=2.368E-4		



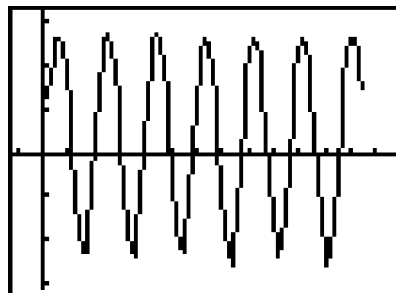
2. Transfer L₂ to L₃. Then using CBL, TI-82(1) and Tuning Fork(2) run the program MIC and collect the data. (You don't need to transfer L₁ since it stays the same throughout the project)
 - A. Raw data is entered in L₅ and L₆
 - B. Adjusted data is entered in L₁ and L₂
 - C. Then plot the information using STAT PLOT

L1	L2	L3
RAW DATA	.32745	-----
5.7E-4	.33212	
8.3E-4	.30226	
.00108	.26196	
.00133	.18248	
.00158	.07948	
.00183	-.0414	
L1(1)=2.368E-4		



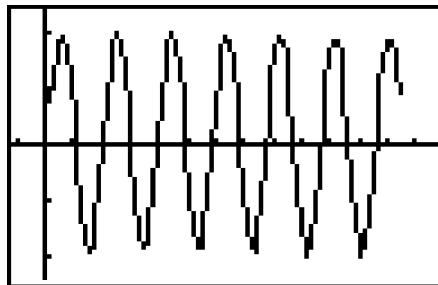
3. Transfer L₂ to L₄. Then add L₃+L₄ and put the result in L₅. Plot the information using STAT PLOT.

L3	L4	L5
.32745	.28995	RAW DATA
.33212	.54837	.88049
.30226	.78309	1.0853
.26196	1.0081	1.2701
.18248	1.1189	1.3014
.07948	1.0932	1.1727
-.0414	.93981	.89839
L5(1)=.617405		

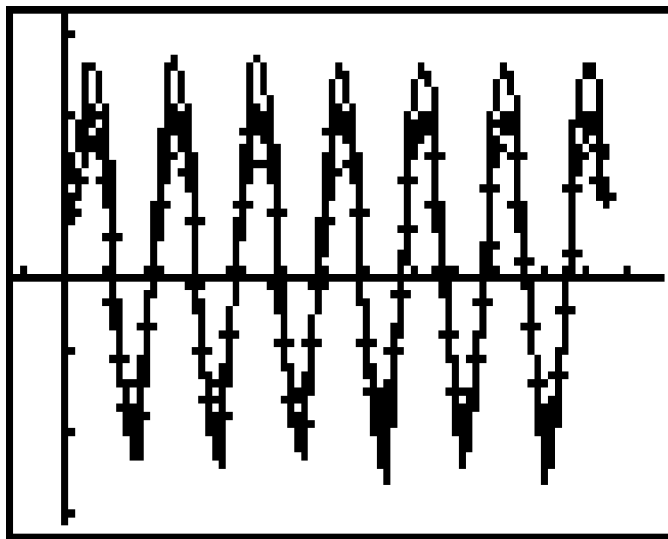


4. Clear L_2 . Then using CBL, TI-82(2) and both Tuning Forks run the MIC program and collect the data. Then transfer L_2 from TI-82(2) to TI-82(1). Plot the information using STAT PLOT.

L1	L2	L3
DATE	.36943	.32745
5.7E-4	.59333	.33212
8.3E-4	.77581	.30226
.00108	.92582	.26196
.00133	.96164	.18248
.00158	.83962	.07948
.00183	.56646	-.0414
L1(1)=2.368E-4		



5. Then plot both STEP 3 GRAPH (sum of the two individual curves) and STEP 4 GRAPH (the graph of the two tuning forks recorded together) on the same axes.











SUCCESS

1. Before starting this experiment, review with students how to enter data into the statistic lists and graph correlations between the lists on the statistics plots on the TI-82. Use a small list of ten values and place in the TI-82.

- FIG. 1

2. Enter data.
3. Plot both lists by pressing STAT PLOT, ENTER, ON, select type of graph, L_1 , L_2 , and select mark:

```
Plot1
Off
Type:    
Xlist:  L2 L3 L4 L5 L6
Ylist: L1  L3 L4 L5 L6
Mark:  + 
```

1. Change one list to another by placing cursor on destination list title, i.e L_3 .
2. Beside the $L_3 =$ at the bottom of the screen (see FIG. 1), type in L_2 (should be $L_3 = L_2$).
3. Press ENTER to transfer.

1. Place cursor on desired list title.
2. Press CLEAR then ENTER.

IV. Add lists

1. Select destination list title i.e. L_5 .
2. Beside $L_5 = L_2 + L_4$ which is the desired sum and press ENTER.
3. This sum now resides in L_5 .

V. Transfer by linking

1. Link two calculators using unit to unit link.
2. A list from one calculator must transfer into the same list on the other calculator i.e. L_1 to L_1 .
3. Prepare the destination calculator to receive: LINK, RECEIVE, ENTER.
Waiting..... will appear on the screen.
4. Prepare the sending calculator to transfer: LINK, SEND, 3:SELECT CURRENT, Select List Name from menu, TRANSMIT, ENTER.
You may transfer more than one list or program at the same time.

ACTIVITY 1

LAB PROCEDURE

Introduction

A vibrating tuning fork disturbs air molecules and creates compressions (regions of higher than normal pressure) and rarefactions (regions of lower than normal pressure). These pressure variations can be digitized with a microphone, transferred to a calculator, and displayed on its screen as a sinusoidal curve. The addition of two or more of these sinusoidal curves is referred to as superposition. Characteristics of the sound wave such as its period, T can be determined from measuring the distance between the crests of individual waves, i.e., one wavelength. Knowing the wave's period, its frequency, f , is easily computed using the formula: $f = 1/T$. Superposition phenomena explains the amplification of music in a musical arrangement.

Equipment Required

1. CBL unit
2. 2 TI-82 graphics calculators
3. 1 Unit to unit link cable
4. Vernier microphone/amplifier with CBL DIN adapter
5. 2 Tuning forks of the same frequency

Equipment Setup Procedure

1. Connect the CBL unit to the TI-82 calculator with the unit to unit link cable using the I/O ports located on the bottom edge of each unit. Press the cable ends in firmly.
2. Connect the Vernier microphone to the Channel 1 (CH 1) input on the top edge of the CBL unit.
3. Turn on the CBL unit and the calculator.

Instructions (Record all information, graphs and answers on worksheet 1.)

1. Execute the Mic Program on the TI-82.
2. Strike the first tuning fork on your elbow away from the microphone and then bring the center of the vibrating prong region near the microphone. Press the ENTER to collect the sound data.
3. Record and calculate the period, T , of 4 wave crests. Subtract the 1st crest from the 4th crest and then divide the difference by 4.
4. Calculate and record the frequency, f , by dividing 1 by T .
5. Transfer L_2 to L_3 .
6. Repeat steps 2 through 4 with the second tuning fork.
7. Transfer L_2 to L_4 .
8. Transfer $L_3 + L_4$ to L_5 .
9. Set aside calculator 1 and link calculator 2 to CBL unit.

10. Strike the two tuning forks simultaneously away from the microphone and bring the center of the vibrating prongs near the microphone. Press ENTER to collect the sound data.
11. Repeat steps 3 and 4.
12. Transfer data from calculator 2 to calculator 1 into L_1 and L_2 .
13. Plot L_1 and L_2 on STAT PLOT ONE. (ZOOM STAT to graph).
14. Plot L_1 and L_5 on STAT PLOT TWO. (Select a different mark from the mark in STAT PLOT ONE!)
** Both graphs should appear on same plot**

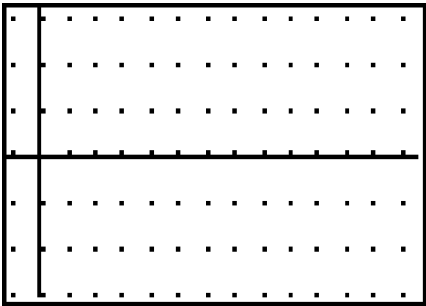
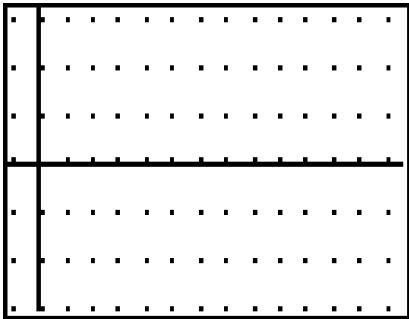
Worksheet #1 Hold that Note

Data NAME_____

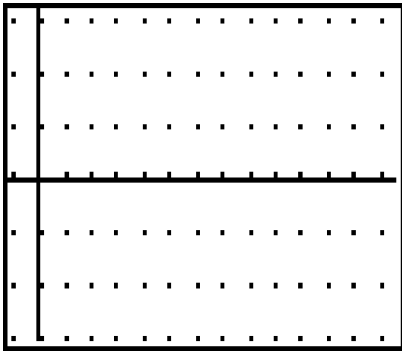
Record the calculations from the experiment in the following table.

	Tuning Fork 1	Tuning Fork 2	Both Tuning Forks
Period (T)			
Frequency (f)			

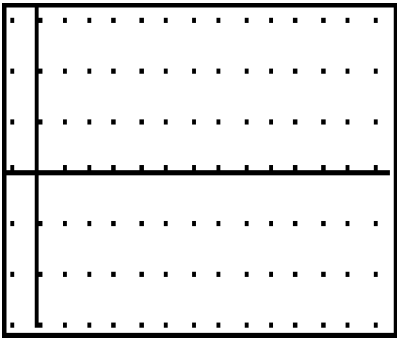
Graphs Tuning Fork 1: Both Tuning Forks (L_1, L_2)



Tuning Fork 2:



Simultaneous (L_1, L_2)
and Sum(L_1, L_2):



Analysis

NAME_____

1. How accurate is the calculated frequency to the marked frequency (Hz) on the tuning forks? What is an acceptable deviation? What causes such a deviation?

2. What do the graphs actually measure? Think about the maximum and minimum points on the graph.

3. Explain frequency in your own words.

4. Explain the significance of the frequency calculated with both tuning forks?

5. What can you conclude from the graph created in the final steps of your experiment?

6. Where might superposition, addition of sound waves, be observed?